AMBIENT AIR QUALITY IN THE SARNIA AREA

ANNUAL REPORT 1983

Ontario
Ministry of the Environment

AMBIENT AIR QUALITY
IN THE
SARNIA AREA

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Technical Support Section
Southwestern Region
ONTARIO MINISTRY OF THE ENVIRONMENT

September, 1984

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SUMMARY

Ambient air quality monitoring in the Sarnia area revealed that the general trend towards lower levels of air pollutants continued in 1983. Improvement in levels of sulphur dioxide was marginal between 1983 and 1982 but 1983 levels are substantially lower than the levels experienced in the 1970's. For the most part levels of sulphur dioxide and suspended particulate are low and compare favourably with other communities in Ontario.

Levels of carbon monoxide and oxides of nitrogen are low and are continually lower than Ontario's criteria for desirable ambient air quality. Levels of total reduced sulphur compounds are generally low but infrequently elevated levels are detected. Total reduced sulphur compounds are usually malodorous. During 1983 one excursion above the criterion for desirable ambient air quality was detected in east Sarnia.

Although there is no long-term trend of increasing levels of ozone, ozone levels exceed the criterion for desirable air quality too frequently. Ozone is a pollutant formed by photochemical reactions involving other pollutants. The photochemical reactions are very dependent on meteorological conditions and as meteorological conditions vary from year-to-year so do ambient levels of ozone. Ozone may be transported hundreds of kilometres or its precursor pollutants may be transported similar distances prior to reacting to form ozone. Conversely, with the proper meteorological conditions, the precursor pollutants may react to produce ozone close to their points of origin. Thus, adequate control of ozone will be dependent on the development of control strategies both locally and internationally. The U.S. Environmental Protection Agency is requiring states

to implement control strategies that will ensure attainment of the U.S. primary air quality standard for ozone by December 31, 1987. Ontario is endeavouring to ascertain the most effective means of controlling ozone. In this regard, several contracts have been let to consultants and an intensive air quality study was conducted in the Sarnia area during July 1984.

INTRODUCTION

The ambient air monitoring network of the Ministry of the Environment measures the levels of a number of pollutants that may directly or indirectly adversely affect health, vegetation or the enjoyment of property. Data on levels of pollutants are compared with Ontario's criteria for desirable ambient air quality. Thus, excursions above these criteria reflect undesirable conditions. Data are also used to determine trends in air quality and therefore, the effectiveness of pollution abatement, as well as to provide information on the effect of specific sources of pollutants and to formulate strategies to control pollution.

Ontario Hydro, the Lambton Industrial Society and private industry also operate ambient air monitors in the Sarnia area. The Ministry conducts phytotoxicology surveys to determine the effects of air pollutants on vegetation.

Emissions from industrial and other sources of pollutants in Ontario are regulated by this Ministry through a Certificate of Approval. In the Sarnia area, there is a special control strategy for sulphur dioxide. This special control strategy requires major sources of sulphur dioxide to provide supplementary control if the ambient levels of sulphur dioxide approach the 24-hour criterion for desirable ambient air quality.

DESCRIPTION OF MONITORING NETWORK

Continuous and intermittent monitors for determining levels of pollutants in ambient air are maintained by the Ministry at sites dispersed throughout the Sarnia area.

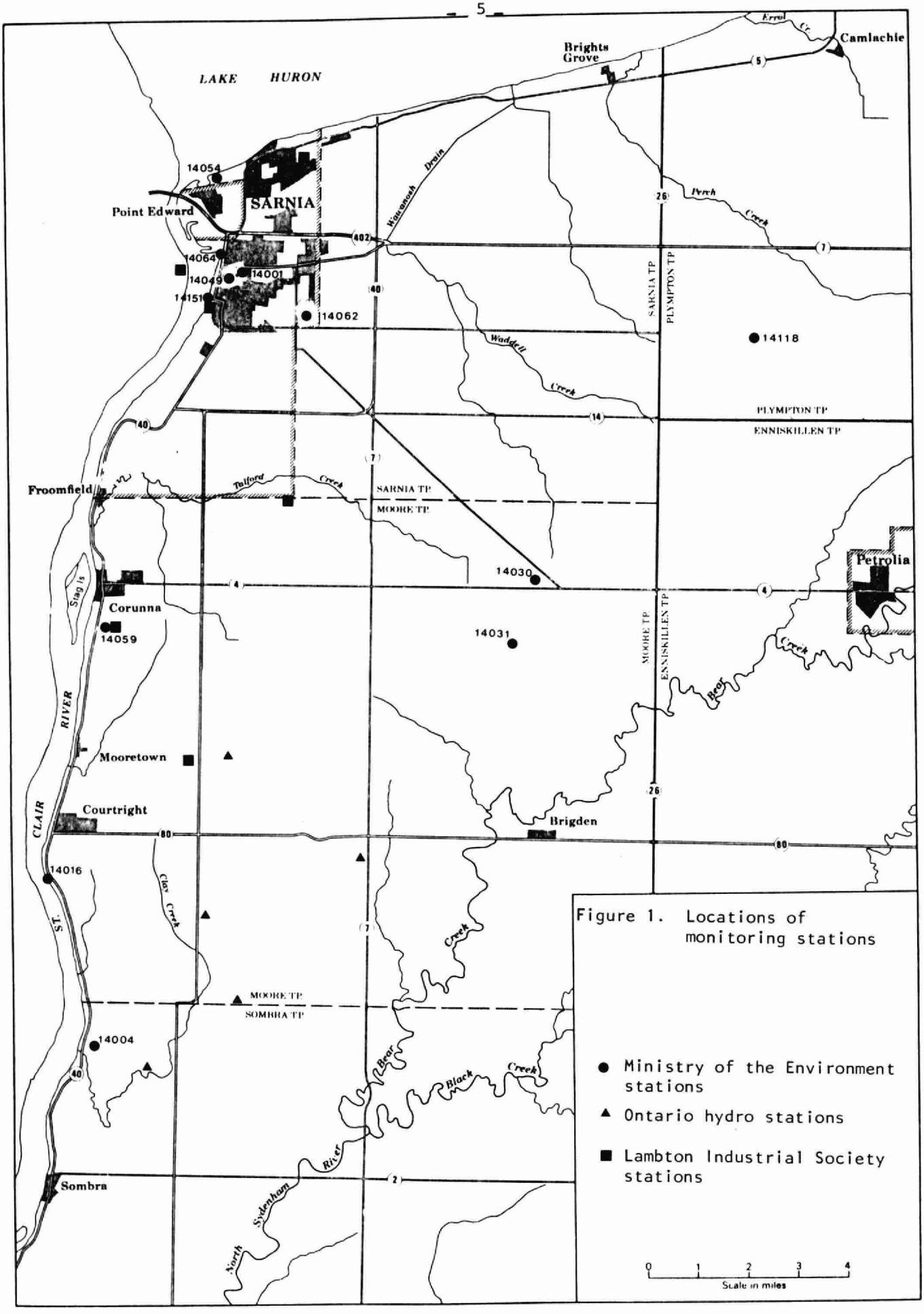
However, monitoring is more intensive in the area of downtown Sarnia because it has a higher potential for elevated levels of pollutants than most other areas in the city. This higher potential is a result of the downtown area being affected by emissions from industries and power plants to the south, as well as by dense vehicular traffic and commercial establishments in the downtown area. The industries and power plants to the south of downtown Sarnia tend to be located along the St. Clair River and plumes from different emissions sources can create an additive impact when they impinge on the downtown area. Furthermore, the taller buildings situated in the downtown core affect wind currents and may bring pollutants from aloft down towards ground level.

The location of the Ministry's fixed monitoring sites are illustrated in Figure 1. Also included in Figure 1 are the locations of monitoring sites of Ontario Hydro and the Lambton Industrial Society. Specific locations and the pollutants monitored are listed in Table A1, Appendix 1.

Criteria for desirable ambient air quality and the supporting rationale for the establishment of these criteria appear in Table A2, Appendix 1.

METEOROLOGICAL DATA

Meteorological data are utilized in predicting the stability of the atmosphere which affects the dispersion of pollutants. These data also assist in identifying sources of elevated levels of pollutants and in validating mathematical models designed to simulate the dispersion of air pollutants.


LAKE HURON
Brights Grove
Errol Cr.
Camlachie
SARNIA
Point Edward
14054
14064
14049
14001
14151
14062
Wawanosh Drain
Perch Creek
SARNIA TP
PLYMPTON TP
14118
Waddell Creek
PLYMPTON TP
ENNISKILLEN TP
Froomfield
Telford Creek
SARNIA TP
MOORE TP
14030
Petrolia
Stag Is
Corunna
14059
14031
MOORE TP
ENNISKILLEN TP
Bear Creek
CLAIR RIVER ST.
Mooretown
Courtright
Brigden
14016
Clay Creek
Creek
MOORE TP
SOMBRA TP
14004
Bear Creek
Black Creek
Sombra
North Sydenham River
Figure 1. Locations of monitoring stations
Ministry of the Environment stations
Ontario hydro stations
Lambton Industrial Society stations
0 1 2 3 4
Scale in miles

The main meteorological tower in the area is located at station 14016 immediately south of Courtright. Wind speed and direction are measured at 10 metres, 30 metres and 92 metres above ground level. In addition, ambient temperature is measured at the 10-metre level and the gradients in temperature between the 10-metre level and the 30- and 92-metre levels are determined. These meteorological data are transmitted to Toronto by a telemetry system. Meteorologists utilize the data to forecast the stability of the atmosphere. This forecasting feature is an intrinsic part of the Air Pollution Index and the Lambton Industrial Meteorological Alert, both discussed later in this report. Wind speed and wind direction are also measured at the 10-metre level of station 14062, located in east Sarnia.

Meteorological data from station 14016 and 14062 have been used to compute the average concentrations of some pollutants for specific wind directions and to determine the number of hours that the criteria for ozone have been exceeded for different wind directions.

A summary of the frequency of winds for different directions at the 30-metre level of station 14016 appears in Table A3, Appendix 2. The data indicate that the prevailing winds are from the south and southwest.

MONITORING PROGRAM AND RESULTS

PARTICULATES

Primary sources of man-caused emissions of particulates to the atmosphere are vehicular traffic, materials handling and combustion processes. Wind-blown particulates from open fields, sand and coal piles, roadways and roofs are also significant sources.

Measurements for particulates are reported as total suspended particulates and soiling index. Total suspended particulates are determined by drawing measured volumes of air through a pre-weighed filter for 24 hours and subsequently weighing the quantity of particulates collected on the filter. Soiling index is measured by determining the difference in the amount of light that is transmitted through a filter before and after ambient air is drawn through the filter for 1 hour. The amount of light transmitted though the filter is affected by the quantity, size, shape and opaqueness of particulates retained on the filter. Soiling index can be correlated to levels of suspended particulates and can be determined without the time-consuming laboratory analysis required for determining concentrations of total suspended particulates. For these reasons, soiling index is used as a substitute for suspended particulate values when data are required quickly such as in the Air Pollution Index.

Total Suspended Particulates

Two criteria for desirable ambient air quality exist for total suspended particulate matter. One is 120 micrograms of suspended particulates per cubic metre of air (ug/m^3) averaged over a 24-hour period. The other is an annual geometric mean of 60 ug/m^3. The criterion for 24

hours is based on impairment of visibility and adverse health effects associated with combined concentrations of sulphur dioxide and suspended particulates. The annual criterion is based on public awareness of suspended particulates and property damage.

During 1983 total suspended particulates were sampled at 9 sites in the Sarnia area. At 8 of the sites sampling was conducted on an every-sixth-day schedule for the year while at the remaining site, station 14016, sampling was conducted on a daily basis. The national monitoring networks of the United States and Canada operate on the same every-sixth-day sampling schedule for suspended particulate matter. The Ministry operates the daily schedule at station 14016 to evaluate how representative the every-sixth-day schedule is of the complete year. The 1983 data indicate that the every-sixth-day schedule was representative of conditions throughout 1983.

Levels of total suspended particulates in 1983 were very similar to 1982 and 1981 levels and appreciably lower than other previous years. This was true for most of southwestern Ontario. In the Sarnia area, the annual criterion was not exceeded during 1982 and 1983. During 1983, the 24-hour criterion was exceeded infrequently at 7 of the 9 monitoring sites and not at all at the remaining 2 sites. The total number of excursions recorded above the 24-hour criterion in the Sarnia area for 1983 was 17 and the total number of valid samples reported was 792. Of the 17 excursions, 5 occurred on May 12, a day that had adverse meteorological conditions which were conducive to elevated levels of suspended particulate matter. A summary of 1983 data for total suspended particulate matter appears in Table 1. Figure 2 shows the annual geometric means and the frequencies of excursions above the 24-hour criterion for 1983 at the approximate locations of monitoring sites.

Table 1. Summary of 1983 data for total suspended particulates.

Station No.	No. of samples collected	Annual geometric mean (ug/m^3)	No. of values greater than 24-hour criterion	Percentage of values greater than 24-hour criterion
14001	57	39	0	0
14016	340	33	2	1
14016-S	57	36	1	2
14030	57	31	0	0
14031	55	37	4	7
14054	57	46	1	2
14059	55	40	1	2
14062	57	44	1	2
14064	57	59	2	4
14151	57	57	6	11

Note: Data for station 14016-S are every-sixth-day sampling results extracted from the daily sampling data for station 14016.

The trend of improved levels of total suspended particulate matter is illustrated by Figure 3. This figure indicates that for 5 monitoring sites [1] in operation since 1972 the average annual geometric mean has been lowered by close to 50 percent and the frequencies of excursions above the 24-hour criterion have been reduced by 80 to 90 percent.

(1) The 5 stations are 14001, 14016, 14054, 14151 and 14064. Stations 14064 replaced station 14049 in 1978 but comparison studies revealed that the levels of suspended particulates were similar.

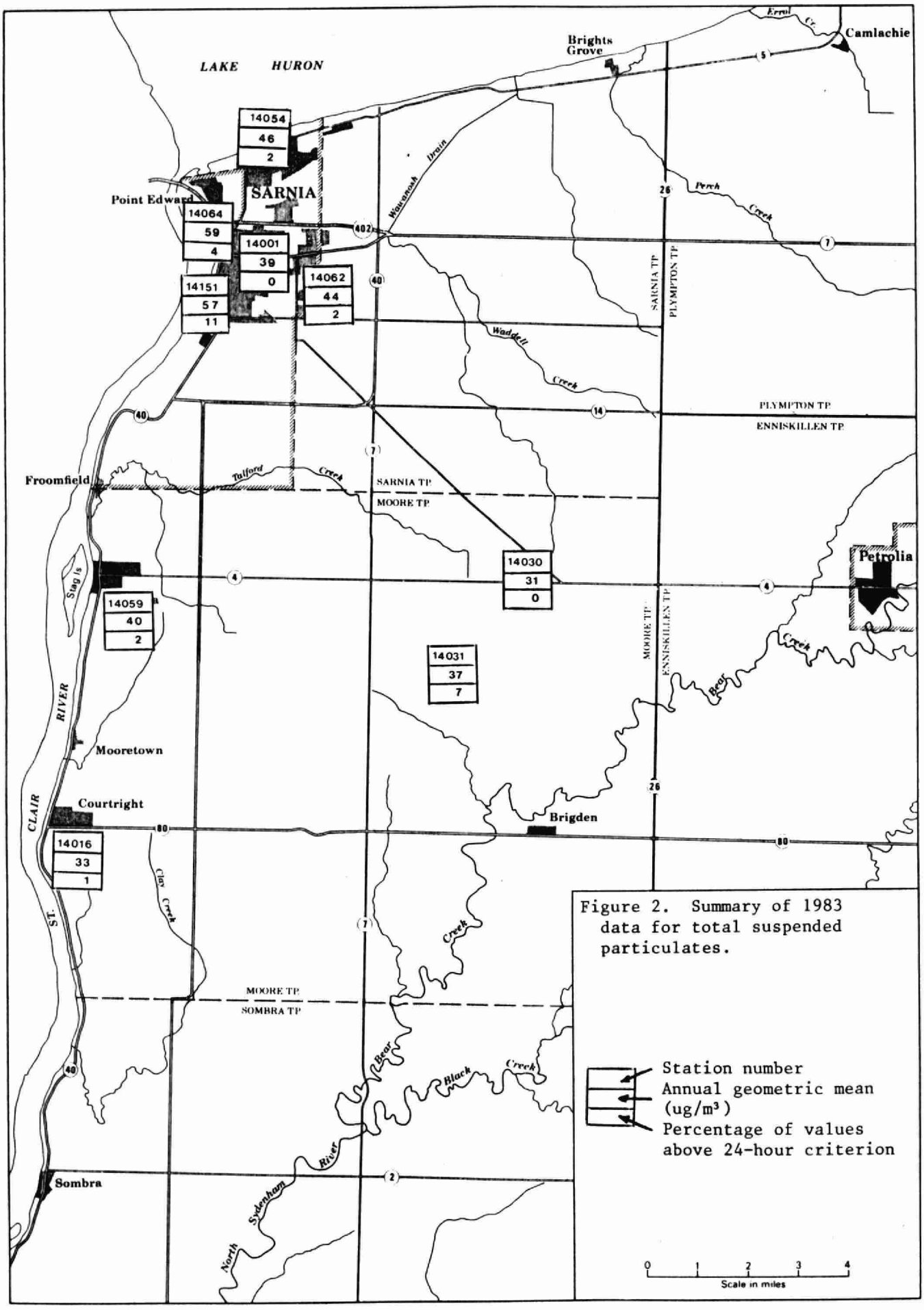
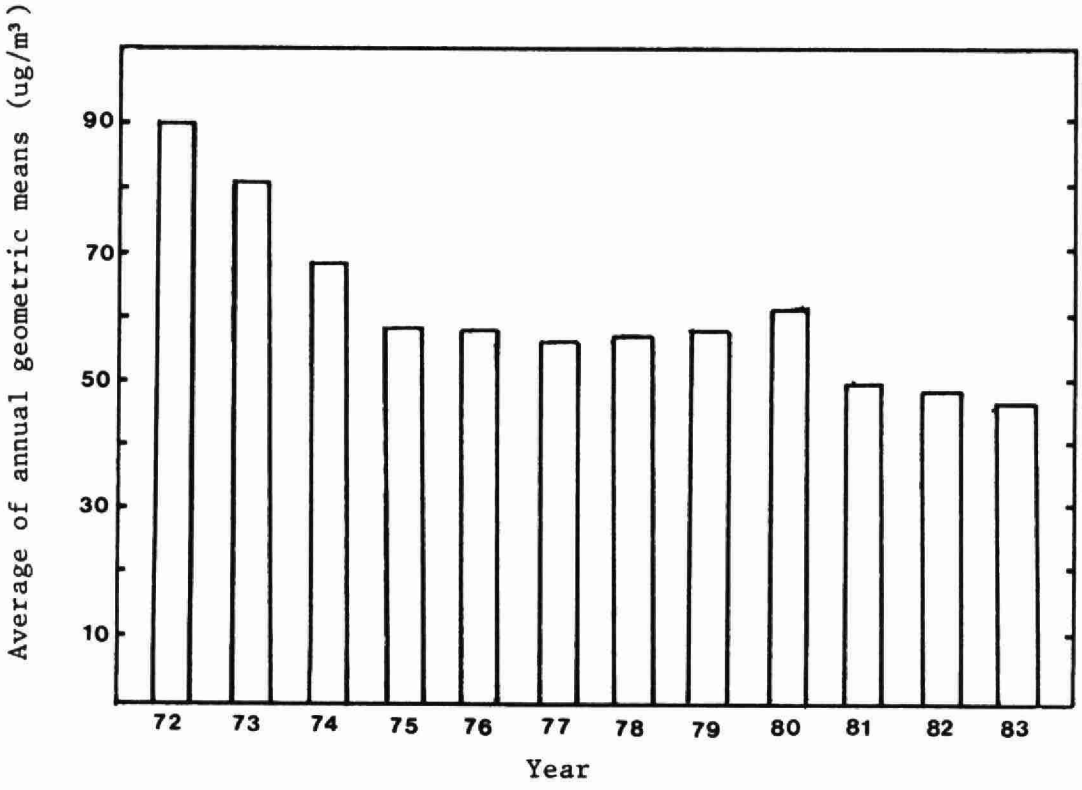
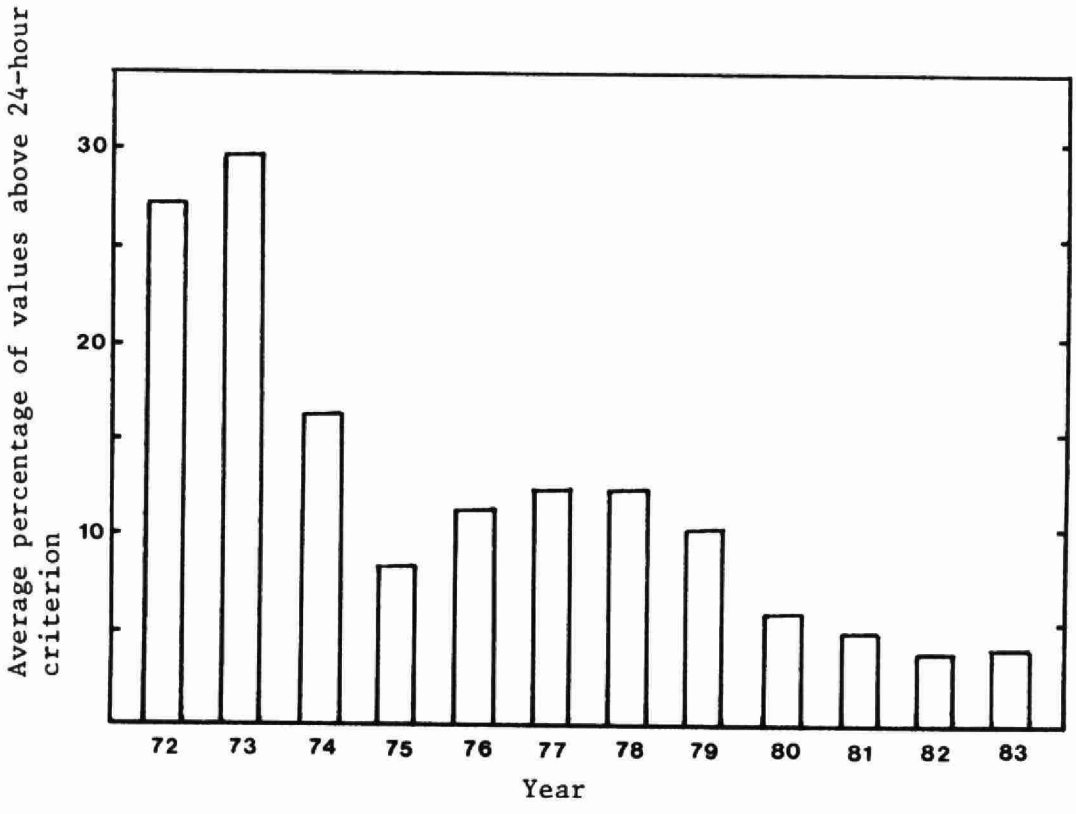


Figure 2. Summary of 1983 data for total suspended particulates.

Figure 3. Trend in levels of total suspended particulates based on data averaged for five monitoring stations.





In general, levels of total suspended particulates in the Sarnia area compare favourably with levels measured in other areas of Ontario. Correlations between 1983 data for wind direction and total suspended particulate matter revealed that higher levels of total suspended particulates occurred at all Sarnia area stations when winds were from the south. This is not surprising since poorer dispersion conditions and southerly winds are frequently associated with the backs of high pressure systems moving in northerly and northeasterly directions. Figure 4 provides the relative correlations at each monitoring station for 1983 data. The longer the line, the greater the correlation.

Chemical Analysis of Suspended Particulates

As part of a Province-wide study, samples of suspended particulates collected at 5 stations in the Sarnia area were analyzed for cadmium, chromium, copper, iron, lead, manganese, nickel, vanadium, nitrates and sulphates. For two additional stations samples were analyzed for nitrates and sulphates and for 1 of the 2 additional sites lead was analyzed. A summary of data from 1976 through 1983 for these constituents is contained in Table A4, Appendix 3. Data for sulphates are erroneously high, based on the findings of several studies of the sampling method utilized by the Ministry. The Ministry is currently investigating different filter media which may lead to more accurate results.

Criteria for desirable ambient air quality exist for cadmium, lead, nickel and vanadium. There have been no values above the criteria and in general, the concentrations of the various metals have been low.

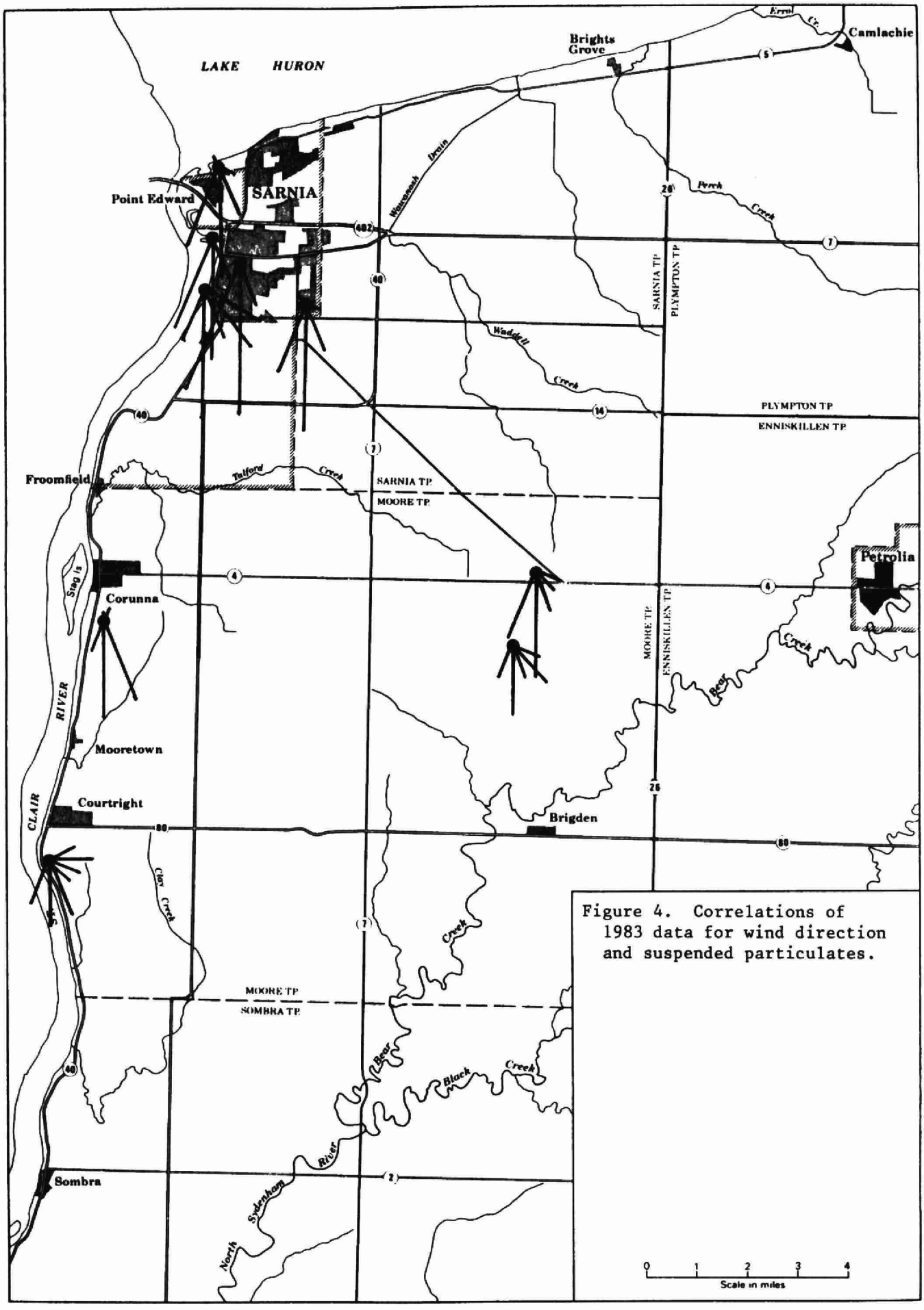


Figure 4. Correlations of 1983 data for wind direction and suspended particulates.

SULPHUR OXIDES

Combustion of sulphur-containing fuels comprises the predominant source of man-made emissions of sulphur oxides. In the Sarnia area, large quantities of these fuels are consumed by power-generating plants in Michigan and Ontario and by petroleum and petrochemical industries located south of downtown Sarnia.

The Ministry of the Environment monitors sulphur oxides in the Sarnia area using continuous analyzers for gaseous sulphur dioxide and by analyzing suspended particulate matter for sulphate.

Sulphur Dioxide

Throughout 1983 the Ministry measured gaseous sulphur dioxide at 4 separate sites in the Sarnia area. There were 12 other sites where monitors providing continuous measurements of sulphur dioxide were operated by Ontario Hydro, the Lambton Industrial Society or private industry. Data for these 12 sites are not included in this report but were utilized to confirm conclusions drawn from the data generated by the Ministry's instruments.

Data are reported as 1-hour average concentrations, 24-hour average concentrations (midnight to midnight) and annual average concentrations. Criteria for desirable ambient air quality are 0.25 parts of sulphur dioxide per million parts of air (ppm) averaged for a 1-hour period, 0.10 ppm averaged for 24 hours and 0.02 ppm as an annual average. The criteria for the 1-hour and annual averages are based on the protection of vegetation while the 24-hour criterion is based on the protection of human health.

In the past, there has been concern about the frequency of excursions above the 24-hour criterion for desirable ambient air quality in the downtown area of Sarnia. This concern resulted in a new regulation called LIMA[1] being implemented in April, 1981. This regulation required major industrial emitters of sulphur dioxide to provide additional controls either continuously or when required by this Ministry. The Ministry may require industry to provide increased controls when meteorological conditions conducive to adverse air quality are likely to persist and sulphur dioxide levels are elevated at specified monitoring sites. This control strategy has been extremely successful. Since the regulation went into effect the 24-hour criterion has not been exceeded at the Ministry's monitoring stations.

Figure 5 shows the decreasing trend in the frequencies of excursions above the 24-hour criterion at Ministry monitoring stations. Station 14064 is located in the downtown area, station 14062 is in east Sarnia, and stations 14004 and 14016 are located south of Courtright. Station 14049 was located in downtown Sarnia but its instrumentation was relocated to station 14064 because of redevelopment in the immediate area of the station. It is very evident that excursions have occurred most frequently in the downtown area of Sarnia and that excursions have not occurred at these stations since LIMA was implemented in 1981.

(1) Lambton Industrial Meteorological Alert

Figure 5. Trend in frequency of excursions above 24-hour criterion for sulphur dioxide, 1972 to 1983.

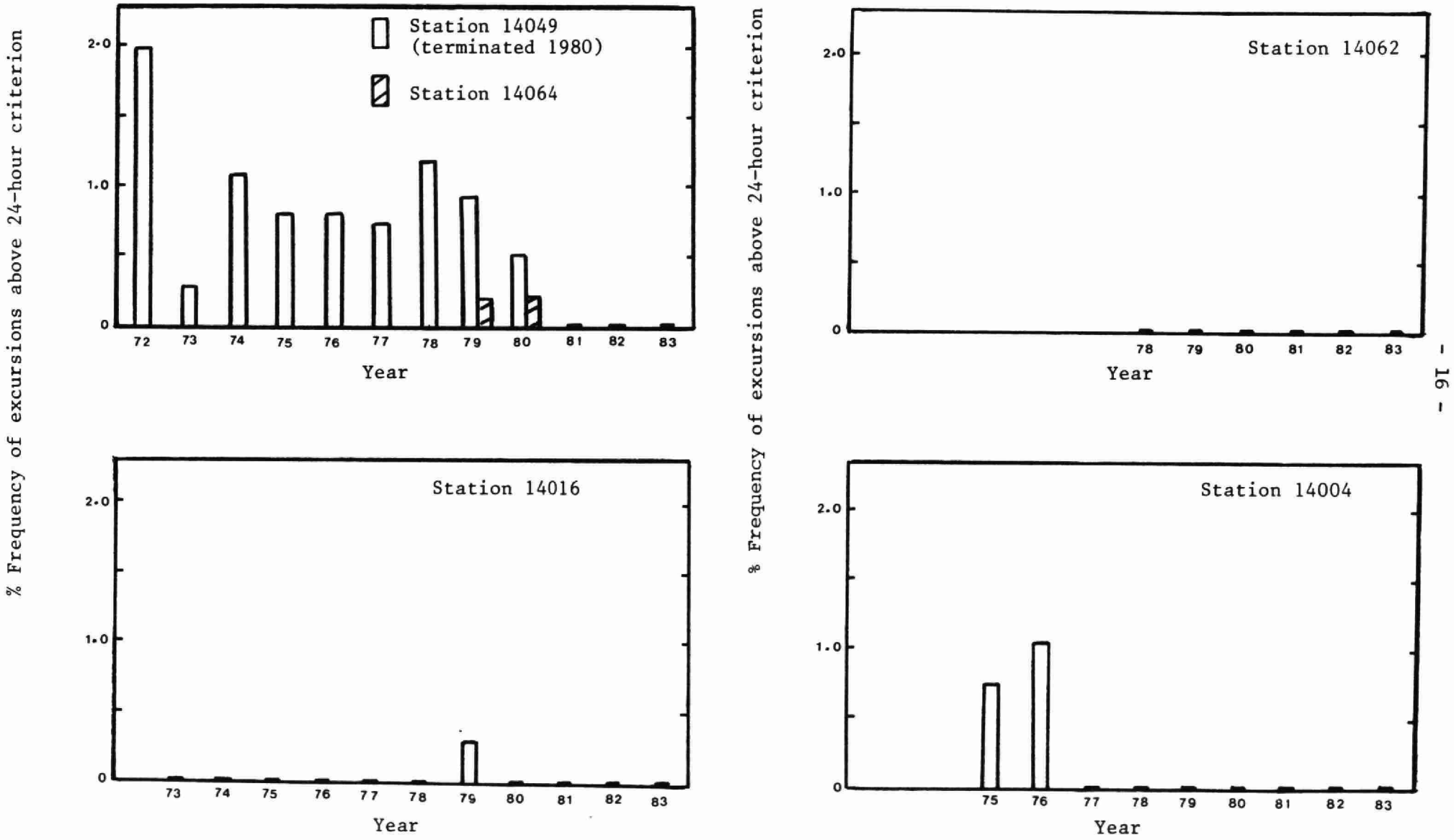
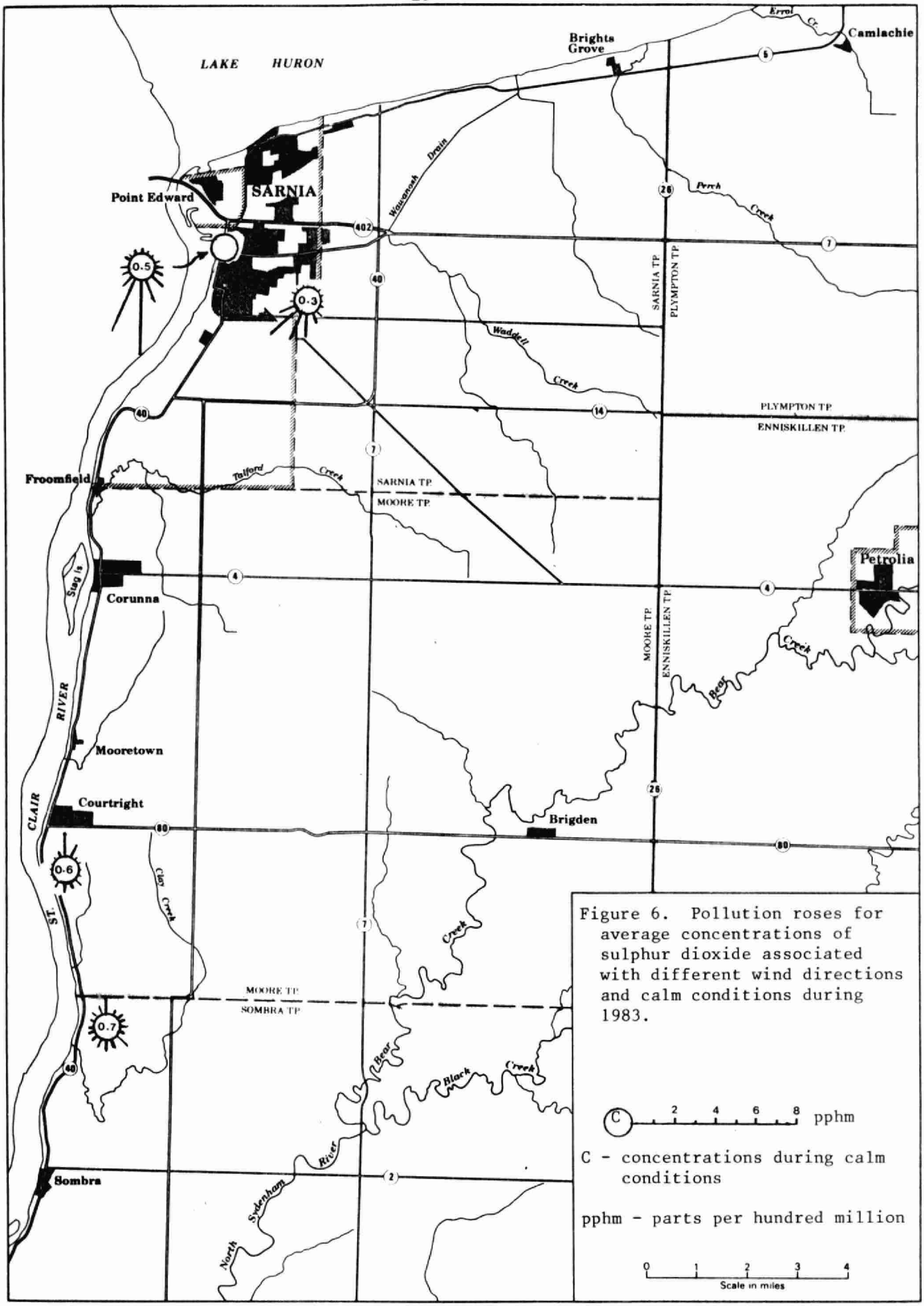


Table 2 contains a summary of 1983 sulphur dioxide data. The annual criterion was not exceeded during 1983. The 1-hour criterion was exceeded on 1 occasion at station 14004, on 3 occasions at station 14016 and not at the other stations. Two of the 3 excursions at station 14016 occurred on September 8, 1982 during calm conditions. The other excursion at station 14016 and the excursion at station 14004 also occurred during calm conditions. All excursions occurred around noon. It was not possible to identify a specific source for these excursions since the calm conditions did not provide reliable wind direction information. There were no reports of unusual activity at any of the major sources of sulphur dioxide in the area. The 1-hour criterion is based on the protection of vegetation and recent annual phytotoxicology surveys by the Ministry have not revealed any damage attributable to sulphur dioxide. Therefore, these rare excursions above the 1-hour criterion are not believed to be creating an air pollution problem.

Table 2. Summary of 1983 data for sulphur dioxide

Station No.	Annual average (ppm)	Percentage of values above criterion 1-hour	24-hour	Maximum 1-hour value (ppm)	Maximum 24-hour (daily) value (ppm)
14004	0.00	0.01	0	0.27	0.04
14016	0.00	0.04	0	0.42	0.04
14062	0.01	0	0	0.24	0.04
14064	0.01	0	0	0.21	0.08

Pollution roses for sulphur dioxide measurements are shown in Figure 6. The roses were created using data for wind direction and speed from the 30-metre level of station 14016 and concentrations of sulphur dioxide determined at the various stations. The length of the line corresponding to a specific wind direction indicates the


LAKE HURON
Brights Grove
Errol Cr.
Camlachie
Point Edward
SARNIA
Wisconsonk Drain
Perch Creek
0.5
0.3
SARNIA TP
PLYMPTON TP
Waddell Creek
PLYMPTON TP
ENNISKILLEN TP
Froomfield
Telford Creek
SARNIA TP
MOORE TP
Petrolia
Sag is
Corunna
MOORE TP
ENNISKILLEN TP
Bear Creek
CLAIR RIVER
Mooretown
Courtright
Brigden
0.6
ST.
Clay Creek
Creek
MOORE TP
SOMBRA TP
0.7
Bear Creek
Black Creek
River
Sombra
North Sydenham
Figure 6. Pollution roses for average concentrations of sulphur dioxide associated with different wind directions and calm conditions during 1983.
C 2 4 6 8 pphm
C - concentrations during calm conditions
pphm - parts per hundred million
0 1 2 3 4
Scale in miles

average sulphur dioxide concentration when the winds are from that direction. The roses for stations 14062 and 14064, located in east Sarnia and downtown Sarnia respectively, reflect appreciably higher levels of sulphur dioxide when winds are blowing from the industries located in south Sarnia and further south. However, since the criteria for desirable ambient air quality are met at these monitoring stations, the influence of the local emission sources is not creating a problem.

The roses for the two stations south of Courtright do not reveal an appreciable impact from the nearby power generating stations of Ontario Hydro and Detroit Edison.

AIR POLLUTION INDEX

The Air Pollution Index (API) is a system designed to control or prevent an air pollution episode. Meteorological forecasting and current readings of sulphur dioxide and suspended particulates are utilized to predict the potential for persistence of pollution conditions that are reported as the API.

Data for suspended particulates are provided by the measurements of soiling index and a correlation between concentrations of suspended particulates and soiling index. Hourly values of soiling index and gaseous sulphur dioxide are used to compute 24-hour running averages which are inserted in the following equation:

$$API = 3.02\ (9.75\ COH + 125.95\ SO_2)^{0.76}$$

Where: COH is the 24-hour running average for soiling index expressed in units of coefficient of haze. SO_2 is the 24-hour running average for sulphur dioxide expressed in parts per million.

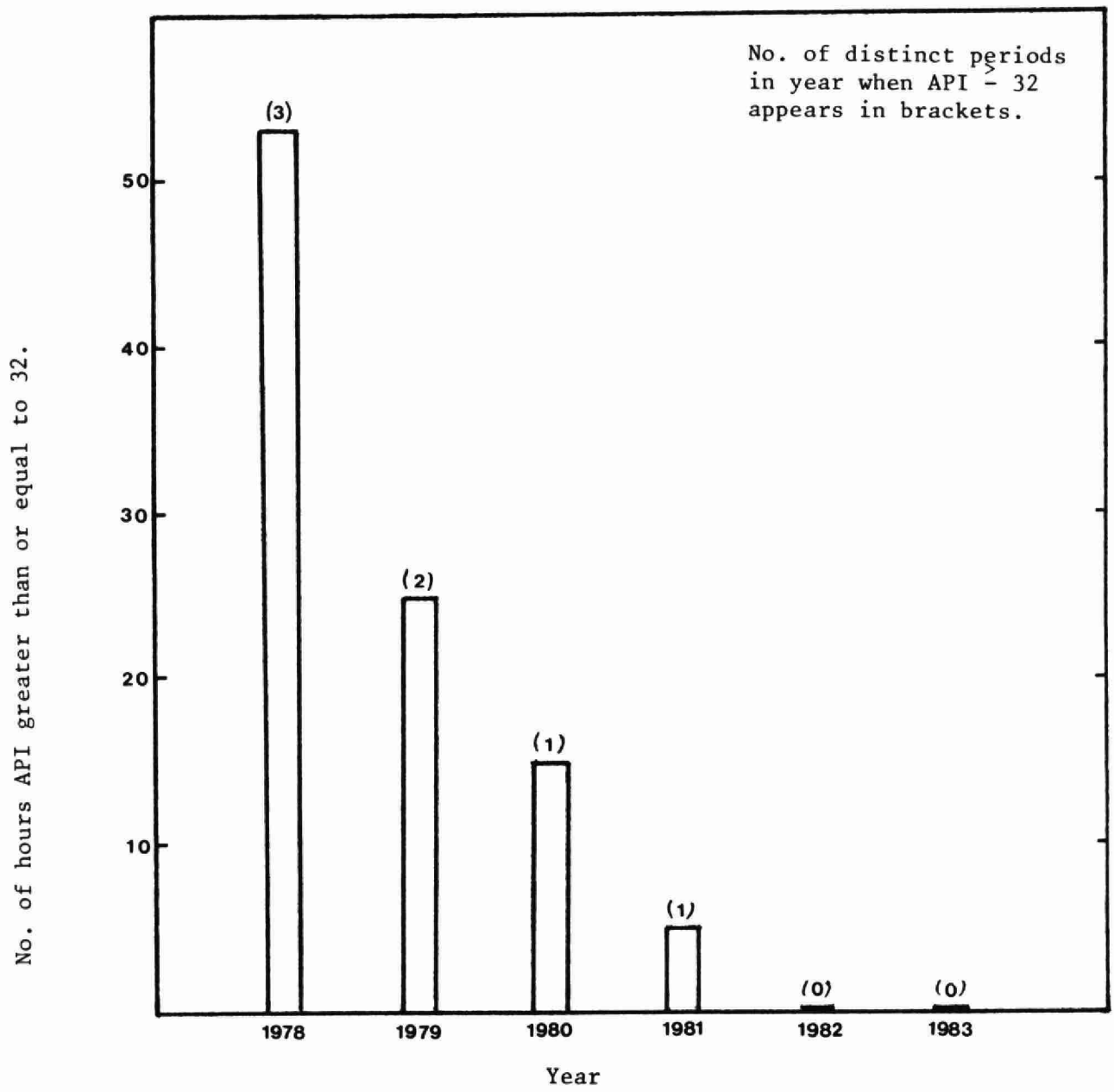
The sulphur dioxide and soiling index data utilized to determine the API for Sarnia are obtained from monitors operated at station 14064 in the downtown core.

API values below 32 are considered acceptable. Values from 32 to 49 are at the Advisory Level and if adverse weather conditions are likely to persist, those responsible for major emissions are advised to prepare to curtail operations. At an API of 50, major emitters may be ordered to curtail operations. At 75, further cutbacks can be required. If the API reaches 100 all industries and other contributors of pollution not essential to public health and safety may be ordered to cease operation.

The LIMA regulation would result in sulphur dioxide emissions being curtailed well before the API reached 50. A very remote possible exception would be if the soiling index were extremely high and levels of sulphur dioxide were low. Since the API was introduced in Sarnia in December, 1977 it has not reached 50.

Since LIMA was introduced in April 1981, API levels have been below 32. A favourable comparison between levels in recent years and levels of the initial years of reporting the API can be seen in Figure 7.

Figure 7. Trend in Air Pollution Index levels.



HYDROGEN SULPHIDE AND MERCAPTANS

Mercaptans are a group of organic compounds that contain sulphur and hydrogen and exhibit characteristics similar to hydrogen sulphide. Hydrogen sulphide is commonly referred to as "rotten egg gas" and many mercaptans are also malodorous at extremely low concentrations.

Both hydrogen sulphide and mercaptans originate in nature from anaerobic decomposition of organic matter containing sulphur. In the Sarnia area, the release of hydrogen sulphide and mercaptans into the atmosphere may result from the processing of petroleum feedstocks containing sulphur.

The criterion established to represent desirable ambient air quality with respect to hydrogen sulphide is 0.02 ppm as an average for 1 hour. This criterion is based on the offensive odours exhibited by this gas. Similarily, the criterion for mercaptans is based on odour and was established as 0.01 ppm averaged for 1 hour and expressed as methyl mercaptan.

Unfortunately, the monitoring instrument in Sarnia does not segregate hydrogen sulphide from mercaptans but determines their combined concentrations and reports these concentrations as hydrogen sulphide. However, the monitoring instrument over-responds to some mercaptans such that the concentration would be reported as more than an equivalent amount of hydrogen sulphide. In consideration of these shortcomings the combined concentrations of hydrogen sulphide and mercaptans are compared to the less restrictive hydrogen sulphide criterion.

During 1983 the hourly criterion of 0.02 ppm was exceeded on one occasion at station 14062, located in east Sarnia. During the excursions winds were from the southwest at moderate speed and the most likely source of the emissions causing the excursion would be situated in the industrialized area of south Sarnia. A pollution rose, Figure 8, constructed with the use of wind speed and direction data from station 14062 indicates higher levels of hydrogen sulphide and mercaptans when winds are blowing from the southwest. Complaints about hydrogen sulphide and mercaptan-like odours are received infrequently by the Sarnia Office of the Ministry. Most of the complaints received pertain to sources outside Sarnia or may be related to upsets at a local industry.

The summary in Table A5, Appendix 4 shows that the data have been similar in recent years with excursions of the 1-hour criterion being very infrequent.

CARBON MONOXIDE

Combustion processes represent man's major emissions of carbon monoxide. Emissions from motor vehicles are most significant because they occur near ground level and are concentrated in urban areas where the public may be exposed for lengthy periods. Industries and power-generating plants normally provide adequate dispersion for their emissions to prevent unsatisfactory levels of carbon monoxide in the ambient air.

The criteria for carbon monoxide, which are based on the protection of human health, are 30 ppm averaged for 1 hour and 13 ppm averaged for any consecutive 8-hour period.

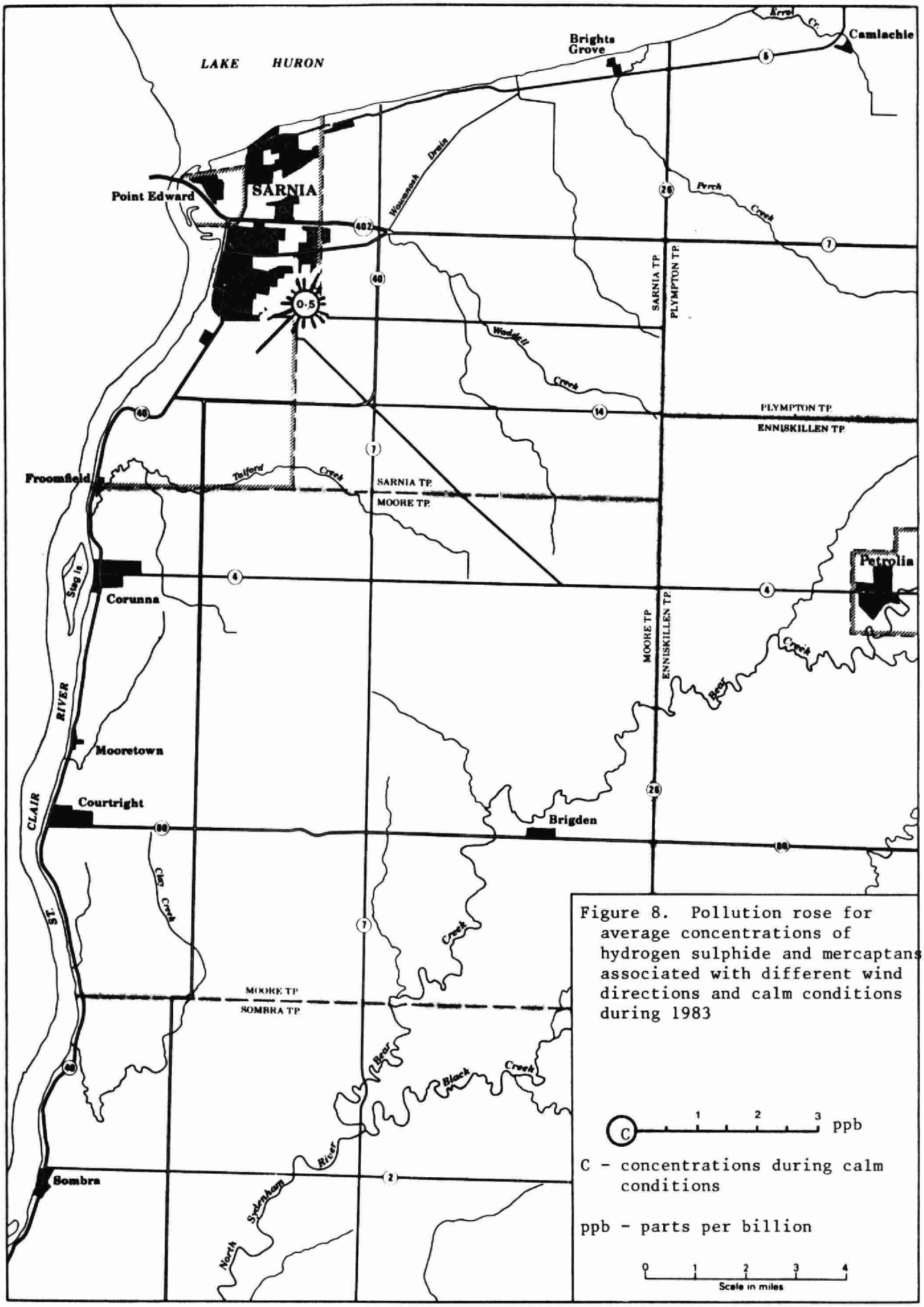


Figure 8. Pollution rose for average concentrations of hydrogen sulphide and mercaptans associated with different wind directions and calm conditions during 1983

C 1 2 3 ppb

C - concentrations during calm conditions

ppb - parts per billion

During 1983 carbon monoxide was monitored at station 14064, located in the downtown core at Centennial Park. The criteria for desirable ambient air quality were not exceeded. Prior to July, 1978 carbon monoxide was measured in downtown Sarnia at station 14049. A summary of data for carbon monoxide obtained since 1974 is presented in Table A5, Appendix 4, and illustrates long-term conformity below established criteria.

OXIDES OF NITROGEN

Gaseous oxides of nitrogen are emitted into the atmosphere by man through combustion processes. Nitric oxide and nitrogen dioxide are the gaseous compounds of primary interest.

Criteria for desirable ambient air quality exist for nitrogen dioxide, but not for nitric oxide or total oxides of nitrogen. The criteria, which are based on offensive odours and the protection of human health, are 0.20 ppm averaged for 1 hour and 0.10 ppm averaged for 24 hours. The 24-hour criterion has not been exceeded since monitoring began in 1972. The only excursions of the 1-hour criterion was recorded at station 14064 in October, 1982. No single source is known to account for the elevated reading. Meteorological conditions were such that dispersion was poor.

Monitoring began at station 14049 in downtown Sarnia in 1972 and in July 1978 the monitoring instrument was relocated to station 14064 in Centennial Park. A summary of data for oxides of nitrogen appears in Table A5, Appendix 4. Levels are in ranges typical of communities the size of Sarnia.

Oxides of nitrogen in combination with reactive hydrocarbons and certain meteorological conditions play an important role in the formation of unsatisfactory levels of photochemical oxidants. Also, oxides of nitrogen react to form acids which are part of acidic precipitation. Therefore, consideration is being given to further controls on emissions of oxides of nitrogen.

HYDROCARBONS

Emissions from motor vehicles are a primary man-made source of hydrocarbons in ambient air. Other significant man-made sources are incomplete combustion of fuels by industries and power plants, and evaporation losses during the manufacture, use, storage and transportation of materials containing volatile hydrocarbons. Natural phenomena also produce many hydrocarbons of which methane is the most abundant.

Owing to the wide range of effects associated with different hydrocarbons at various concentrations, no criteria for desirable ambient air quality have been established for total hydrocarbons. Instead control is achieved by setting criteria for desirable levels of specific hydrocarbons in ambient air and/or establishing standards which control the impact of emissions of specific hydrocarbons.

Values of total hydrocarbons have been measured at station 14064 in Centennial Park since July, 1978. Prior to then monitoring was conducted at station 14049 in the downtown core. Average levels measured at station 14064 have been lower than those measured at station 14049. A summary of data for hydrocarbons appears in Table A5, Appendix 4.

During part of 1977 and again in 1978, the Ministry conducted short-term intensified monitoring in the Sarnia area using mobile vans. These surveys[1] measured specific hydrocarbons throughout the Sarnia area. In 1982 a survey for specific hydrocarbons was conducted in the Vidal St. - Churchill Road area of Sarnia using a mobile monitoring van. This survey focussed on the hydrocarbons styrene and benzene and concluded that emissions were minor during the survey period. The results of this survey are available from the Sarnia District Office.

OXIDANTS

Oxidants in the ambient air are primarily a result of a series of photochemical reactions and inter-reaction involving oxides of nitrogen and non-methane hydrocarbons. The reactions are promoted by certain meteorological conditions such as warm temperatures and intensive sunshine, resulting in higher levels of oxidants in the spring and summer months.

Throughout 1983 the Ministry monitored oxidants in the form of ozone at station 14064 in the downtown core of Sarnia, and at station 14118, situated in a rural setting approximately 10 kilometres east of Sarnia. Ozone normally accounts for 80 to 95 percent of the oxidants present in

(1) Report on Ambient Air Surveys in the Sarnia Area, April, May and June, 1977, October and November, 1978. ARB-TDA Report No. 03-81, Ministry of the Environment, March, 1981.

ambient air. Consequently, with technology for monitoring ozone being more accurate and efficient than for total oxidants, most regulatory agencies monitor for ozone.

Long-range transport of ozone and its precursor chemicals (oxides of nitrogen and hydrocarbons) may account for a very significant portion of local levels of ozone. Long-range transport from distances greater than 200 kilometres has been reported in the literature. Therefore, successful control of oxidants will depend on control strategies implemented in the United States as well as in Ontario. The United States and Canada have been jointly addressing the significance of long-range transport of ozone and its precursor chemicals. In 1981 this Ministry participated in a study of the impact of emissions from the Detroit area on downwind ozone levels. This study resulted in a proposal by the State of Michigan to the U.S. Environmental Protection Agency (EPA) for the control of oxidants in areas downwind of Detroit through the reduction of non-methane hydrocarbons in the Detroit area. The State of Michigan is revising the proposal to assure its acceptance by EPA. The control plan is to allow the U.S. primary air quality standard for ozone (0.12 ppm averaged for 1 hour) to be attained by December 31, 1987. Ontario has launched a detailed study into oxidants and oxidant control strategies. Part of Ontario's program will be a detailed air quality study in the Sarnia area during 1984.

In addition to ozone formed by photochemical reactions in the troposphere, ground level concentrations of ozone are occasionally increased by ozone from the stratosphere being transported downward. Ozone is naturally produced in minor amounts by lightning.

Ontario's criterion for desirable ambient air quality established for ozone is 80 parts per billion (ppb)

averaged for 1 hour. This criterion was established for the protection of vegetation, property and human health. Some oxidant-related effects that are detrimental to health are eye irritation and a decrease in performance during athletic endeavours.

During 1983 the criterion was exceeded 116 times at station 14064 and 16 times at station 14118. At both monitoring stations, the frequency of excursions was more than in previous years. The increase was especially apparent at station 14064 where there would tend to be more ozone formed by local emissions. Meteorological conditions during the summer of 1983 were more favourable for oxidant formation due to the warmer temperature and greater solar radiation. A summary of data for ozone appears in Table A6 of Appendix 4.

Pollution roses for 1983 are presented in Figure 9 to show the frequency of the total number of excursions above the criterion associated with different wind directions. The greatest frequency of excursions are associated with southerly and south-southwesterly winds. These winds are apt to be associated with the backs of high pressure systems or the area south of low pressure fronts which have weather favourable for photochemical reactions (clear sunny skies and warmer temperatures) and which promote long-range transport of oxidants and their precursor chemicals.

FLUORIDES

In the Sarnia area fluoride is emitted into the atmosphere from fosil-fueled power plants where it exists as an impurity in coal, from a fertilizer plant where it occurs as a constituent of phosphorus rock, and from petroleum refineries where it is used as a catalyst in alkylation.

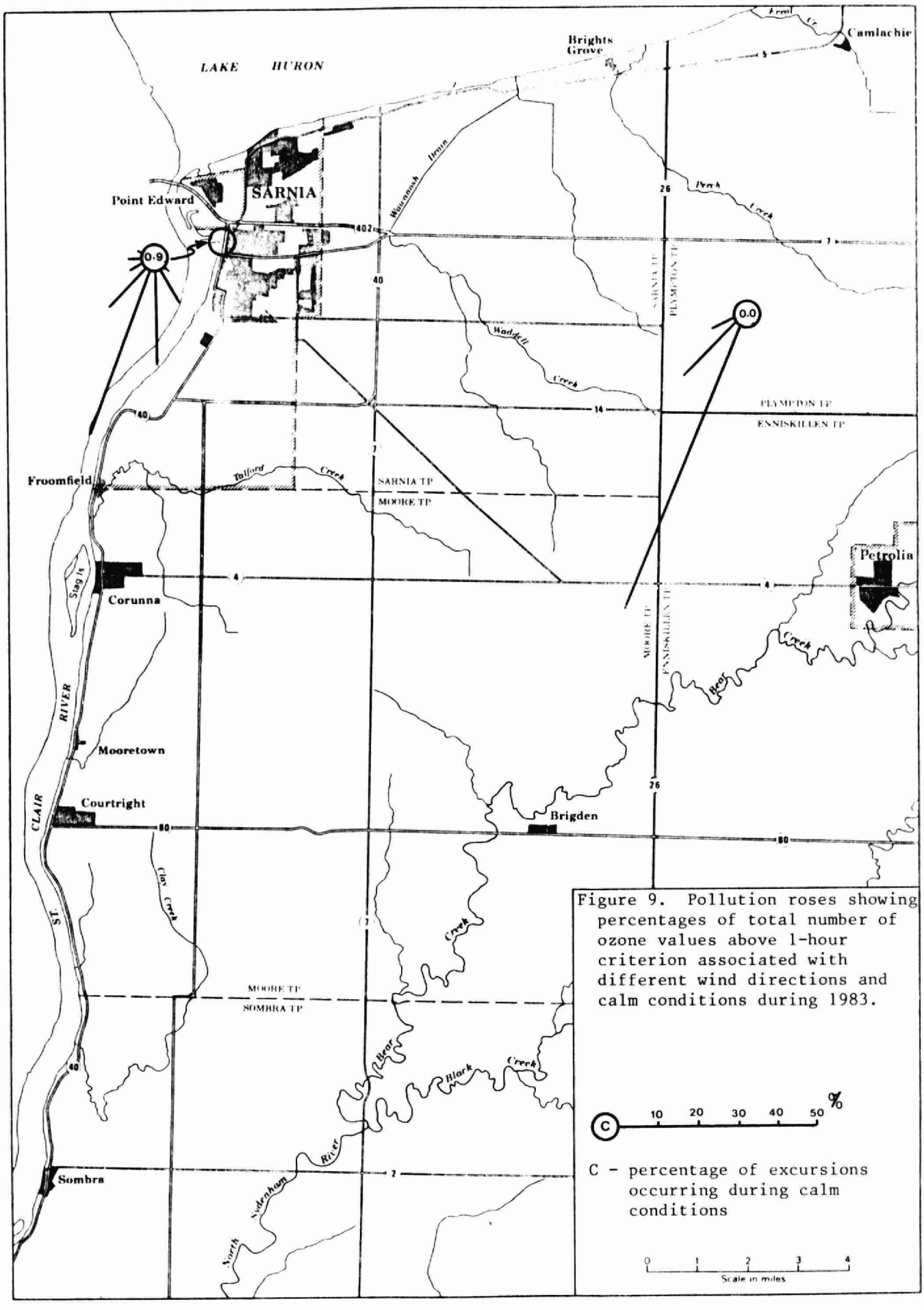


Figure 9. Pollution roses showing percentages of total number of ozone values above 1-hour criterion associated with different wind directions and calm conditions during 1983.

Fluoridation rate is a measurement designed to indicate relative amounts of gaseous fluoride present over an extended period of time. A lime-impregnated filter is exposed to ambient air for thirty days and subsequently analyzed for fluoride content. This technique is inexpensive compared to other methods for measuring airborne fluorides. Some fluorides in particulate form are collected on the filters.

Criteria for desirable ambient air quality established for fluoridation rate are based on protection of vegetation. A criterion of 40 micrograms of fluoride per 100 square centimetres of filter per 30 days (ug F/100 cm^2/30 days) exists for the growing season of April 15 to October 15. A less stringent criterion of 80 ug F/100 cm^2/30 days exists for the period of October 16 to April 14. Since the months of April and October are common to both criteria and fluoridation rate is determined on a monthly basis, excursions above the criteria during these months are determined by comparing fluoridation rate to the average of the two criteria (60 ug F/100 cm^2/30 days).

The Ministry monitors fluoridation rate at station 14004, located south of Courtright in the vicinity of the fertilizer complex of Canadian Industries Limited and power generating plants of Ontario Hydro and Detroit Edison. Canadian Industries Limited has maintained a detailed monitoring network for fluoridation rate for many years and also operates a continuous fluoride analyzer.

The fluoridation rate values determined for the growing season of 1983 were all above the criterion for desirable ambient air quality. However, as in previous years, the 1983 phytotoxicology survey conducted by the Ministry did not reveal vegetation damage attributable to fluoride off company property. Table 3 presents the data for fluoridation rate from 1976 through 1983.

Table 4. Fluoridation rates measured at station 14004 from 1976 to 1983 (ug F/100 cm^2/30 days)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Average
1976						46	38	74	48	39	21	40	44
1977	42	23	53	32	78	31		79	112	29	104	50	58
1978	83	51	53	57	100	65	94	74	74	57	53	59	68
1979	32	63	25	56	54	64	68	129	89	49	32	26	57
1980	16	23	51	62	61	49	83	84		36	28	31	48
1981	48	48	30	49	69	78	116	122	95	71	55	24	67
1982	48	67	35	35	99	20	50		38	86	35	20	48
1983	17	30	37	42	43	75	60	68	42	73	30	30	46

NOTE: Underlined values exceeded criteria for desirable ambient air.

APPENDIX I

MONITORING NETWORK

Table A1. Locations of monitoring stations and parameters being monitored.

Station No.	Location	Parameters measured	Height of measurements	Purpose of stations and comments
14001	Sarnia General Hospital	Suspended particulates	16 m.	Historical station which has been in operation since 1962. Does not reflect ground level concentrations but does indicate more direct effects of particulates from high stacks and long-range transport.
14004	5½ miles south of Courtright	Continuous SO_2 fluoridation rate	4 m.	Monitors SO_2 from power generating stations and fluorides from fertilizer industry.
14016	1¼ miles south of Courtright	Suspended particulates continuous SO_2, WS, WD, Temp., WS, WD, Temp., WS, WD, Temp., telemetering equipment	1 m. 10 m. 30 m. 92 m.	Monitors suspended particulates and sulphur dioxide in relation to power generating plants. Provides meteorological data required for stability forecasts and air quality interpretations.
14030	R. R. #1 Corunna	Suspended particulates	3 m.	Monitors particulates in the vicinity of of Tricil Limited.
14031	R. R. #1 Mooretown	Suspended particulates	3 m.	Monitors particulates in the vicinity of Tricil Limited.
14049	Victoria Street	Continuous SO_2, CO, NO, NO_2 NO_x, O_3, total hydrocarbons, and suspended particulates	4 m.	Monitored air pollutants in a heavily populated area where the pollutants from traffic, commercial establishments and the heavily industrialized complex south of the monitoring station should be high relative to residential areas. This site was terminated in 1978 and the instruments moved to station 14064.

Table A1. continued

Station No.	Location	Parameters measured	Height of measurements	Purpose of stations and comments
14054	Sarnia Yacht Club	Suspended particulates	5 m.	Monitors suspended particulates in the north Sarnia-Point Edward area.
14059	Riverbend, Corunna	Suspended particulates	4 m.	Monitors suspended particulates in the residential area of Corunna which is surrounded by industry and generating stations.
14062	Eastland Plaza, 242A Indian Rd. S.,	Continuous SO_2, H_2S & mercaptans WS, WD	6 m. 10 m.	Monitors SO_2, H_2S and mercaptans in residential-commercial area of east Sarnia which is adjacent to refinery operations. Provides meteorological data useful in identifying sources of pollutants.
14064	Centennial Park Front Street, Sarnia	Continuous SO_2, CO, NO, NO_2, NO_x, O_3, total hydrocarbons, 1-hr COH, suspended particulates, telemetering equipment	3 m.	Monitors main air pollutants in an area adjacent to downtown Sarnia and in line with many point sources of pollution located to the south of the downtown area. Provides Air Pollution Index for Sarnia.
14118	Petrolia Public Utilities Commission Pumping Station, 4 miles west of Wyoming.	O_3	5 m.	Monitors ozone levels in a rural location
14151	Front and David Streets, downtown Sarnia	Suspended particulates	3 m.	Monitors pollutants in commercial area which is also affected by heavily industrialized area to south. Since this is the location of a monitoring station operated by the Lambton Industrial Society, cross checking of monitoring techniques is possible.

Table A2. Desirable ambient air quality criteria established for Ontario

Parameter	Desirable ambient air quality criteria	Prime reasons for establishing criteria or monitoring parameter
Carbon monoxide	30 ppm averaged for 1 hour	Protection of human health
	13 ppm averaged for 8 hours	Protection of human health
Fluoridation rate	40 ug F/100 cm^2 of limed filter paper in 30 days during April 15 to October 15.	Protection of vegetation
	80 ug F/100 cm^2 of limed filter paper in 30 days during October 16 to April 14.	Protection of vegetation (less restrictive criterion during the non growing season)
Total Hydrocarbons	NONE	Effects of hydrocarbons vary widely depending on their chemical-physical nature. Certain non-methane hydrocarbons may react photochemically to produce oxidants.
Hydrogen sulphide	0.02 ppm averaged for 1 hour	Protection against offensive odours.
Mercaptans	0.01 ppm averaged for 1 hour	Protection against offensive odours.
Nitric oxide	NONE	Reacts with oxygen to produce NO_2.
Nitrogen dioxide	0.20 ppm averaged for 1 hour	Protection of human health and protection against offensive odours.
	0.10 ppm averaged for 24 hours	Protection of human health and protection against offensive odours.

Table A2. continued

Parameter	Desirable ambient air quality criteria	Prime reasons for establishing criteria or monitoring parameter
Oxides of nitrogen	NONE	
Ozone	0.08 ppm averaged for 1 hour	Protection of vegetation, adverse health effects
Sulphur dioxide	0.25 ppm averaged for 1 hour	Protection of vegetation
	0.10 ppm averaged for 1 day (24 hours)	Protection of human health
	0.02 ppm averaged for 1 year	Protection of vegetation
Suspended particulates	120 ug/m^3 averaged for 24 hours	Based on health effects in conjunction with elevated levels of SO_2 and impairment of visibility.
	A geometric mean of 60 ug/m^3 during 1 year	Based on public awareness of visible pollution
Cadmium in suspended particulates	2.0 ug/m^3 averaged for 24 hours	Protection of human health
Lead in suspended particulates	5 ug/m^3 averaged for 24 hours	Protection of human health
	A geometric mean of 2 ug/m^3 over a 30-day period	Protection of human health
Nickel in suspended particulates	2.0 ug/m^3 averaged for 24 hours	Protection of vegetation
Vanadium in suspended particulates	2.0 ug/m^3 averaged for 24 hours	Protection of human health

APPENDIX 2

METEOROLOGICAL DATA

Table A3. Percent frequencies of wind directions at the 30-metre level of station 14016.

Year	N	NE	E	SE	S	SW	W	NW
1983	13.5	10.6	7.5	9.3	18.9	15.6	10.2	14.4
1982	12.1	9.5	5.2	8.9	22.4	16.4	12.6	12.9
1981	13.8	9.9	4.5	7.8	18.6	15.8	11.9	17.7
1980	12.6	8.6	5.6	7.5	20.1	15.1	14.4	16.1
1979	10.7	8.7	6.5	8.9	24.7	14.7	11.9	14.0
1978	13.6	12.7	6.3	6.0	19.0	17.2	11.9	13.3
1977	11.3	9.8	5.3	7.2	18.5	21.2	14.1	12.6
1976	12.2	9.2	3.5	4.7	18.1	20.5	15.1	16.7
1975	9.4	11.6	6.7	7.6	19.3	20.5	12.9	12.1
1974	12.2	10.6	5.2	5.7	20.6	21.6	12.1	12.1
1973	11.6	11.0	8.1	7.2	15.8	20.6	12.9	12.8
1972	15.8	12.0	6.5	8.3	17.4	16.4	11.7	12.0

APPENDIX 3

PARTICULATES

Table A4. Concentrations (ug/m^3) of various constituents of suspended particulates: 1976 to 1983.

Station and Year	Cadmium # of samples	Cadmium Avg.	Cadmium Max.	Chromium # of samples	Chromium Avg.	Chromium Max	Copper # of samples	Copper Avg.	Copper Max	Iron # of samples	Iron Avg.	Iron Max	Lead # of samples	Lead Avg.	Lead Max
14001															
1976	10	0.001	0.004	10	0.017	0.066	10	0.31	0.73	10	1.0	2.4	10	0.3	0.6
1977	18	0.000	0.003	18	0.009	0.030	18	0.68	2.48	18	1.2	5.8	18	0.3	1.3
1978	24	0.001	0.005	24	0.010	0.023	24	0.22	0.54	24	1.1	4.0	24	0.2	0.7
1979	32	0.001	0.003	32	0.003	0.013	32	0.23	0.62	32	0.8	3.0	32	0.2	0.4
1980	24	0.001	0.004	24	0.001	0.007	24	0.19	0.56	24	0.9	2.3	24	0.3	0.5
1981	54	0.001	0.003	54	0.003	0.014	54	0.12	0.29	54	0.7	2.6	54	0.2	0.4
1982	57	0.001	0.003	53	0.003	0.011	58	0.19	0.81	54	0.5	1.9	56	0.2	0.6
1983	34	0.001	0.009	34	0.003	0.022	34	0.30	0.93	34	0.6	2.4	34	0.1	0.5
14016															
1976	18	0.000	0.003	18	0.003	0.011	18	0.41	1.17	18	0.6	1.6	18	0.2	0.4
1977	21	0.000	0.002	21	0.008	0.025	21	0.31	0.58	21	0.6	1.8	21	0.2	0.6
1978	26	0.001	0.003	26	0.007	0.019	26	0.50	1.38	26	0.9	3.2	26	0.1	0.4
1979	35	0.001	0.004	35	0.002	0.010	35	0.39	1.01	35	0.8	2.9	35	0.2	0.6
1980	25	0.001	0.004	25	0.002	0.009	25	0.44	0.96	25	0.6	1.8	25	0.1	0.4
1981	124	0.001	0.004	124	0.003	0.014	124	0.19	1.59	124	0.6	2.6	124	0.1	0.3
1982	338	0.001	0.004	328	0.002	0.116	339	0.28	1.71	308	0.4	3.1	328	0.1	0.4
1983	339	0.001	0.004	332	0.002	0.015	339	0.34	1.72	339	0.5	3.6	340	0.1	0.4
14030															
1978	11	0.002	0.004	11	0.007	0.019	11	0.37	0.98	11	1.2	2.2	11	0.3	0.9
1979	50	0.001	0.004	50	0.007	0.022	50	0.32	1.36	55	0.6	2.2	54	0.1	0.4
1980	52	0.001	0.004	52	0.003	0.023	52	0.47	2.34	52	0.5	1.5	52	0.1	0.3
1981	58	0.001	0.009	58	0.005	0.053	58	0.17	0.56	58	0.7	4.5	58	0.1	1.4
1982	58	0.001	0.002	55	0.003	0.010	58	0.11	0.29	48	0.5	3.5	56	0.1	0.7
1983	54	0.001	0.004	55	0.003	0.018	57	0.17	0.45	57	0.4	1.4	57	0.1	0.2

Table A4. continued

Station and Year	Cadmium # of samples	Cadmium Avg.	Cadmium Max.	Chromium # of samples	Chromium Avg.	Chromium Max	Copper # of samples	Copper Avg.	Copper Max	Iron # of samples	Iron Avg.	Iron Max	Lead # of samples	Lead Avg.	Lead Max
14031															
1978	12	0.002	0.003	12	0.004	0.008	12	0.44	1.00	12	0.7	1.3	12	0.1	0.3
1979	54	0.001	0.005	54	0.010	0.189	54	0.25	0.97	58	0.5	2.7	54	0.1	0.4
1980	54	0.001	0.004	54	0.005	0.030	54	0.13	0.26	54	0.5	2.2	54	0.1	0.3
1981	58	0.001	0.003	58	0.005	0.035	58	0.15	0.95	58	0.6	2.6	58	0.1	0.2
1982	54	0.000	0.002	56	0.004	0.010	58	0.13	0.29	50	0.5	3.7	56	0.1	0.6
1983	55	0.001	0.001	53	0.002	0.012	55	0.25	1.54	55	0.6	2.3	55	0.1	0.3
14064															
1981	57	0.001	0.004	57	0.003	0.013	57	0.17	0.86	57	0.7	2.3	59	0.1	0.6
1982	52	0.001	0.008	47	0.002	0.009	52	0.21	1.66	53	0.7	2.9	50	0.2	1.1
1983	57	0.001	0.003	57	0.002	0.009	57	0.62	2.50	57	0.7	1.8	56	0.2	0.6
14054															
1976													3	0.2	0.3
1977													15	0.2	0.5
1978													57	0.2	1.3
1979													55	0.2	1.1
1980													53	0.2	1.0
1981													57	0.1	0.3
1982													55	0.2	0.8
1983													24	0.1	0.3

Table A4. continued

Station and Year	Manganese # of samples	Manganese Avg.	Manganese Max.	Nickel # of samples	Nickel Avg.	Nickel Max	Nitrate # of samples	Nitrate Avg.	Nitrate Max	Sulphate # of samples	Sulphate Avg.	Sulphate Max	Vanadium # of samples	Vanadium Avg.	Vanadium Max
14001															
1976	2	0.30	0.37	10	0.029	0.107	58	3.8	15.8	58	8.6	44.6	10	0.02	0.11
1977	18	0.04	0.23	18	0.014	0.064	47	4.7	24.5	48	12.9	43.9	18	0.01	0.07
1978	24	0.08	0.58	24	0.010	0.033	52	4.6	21.3	51	11.1	39.7	24	0.00	0.02
1979	32	0.06	0.38	32	0.010	0.076	54	4.8	16.0	54	11.0	35.7	32	0.01	0.07
1980	24	0.03	0.13	24	0.010	0.033	55	5.5	18.4	55	13.4	28.6	24	0.01	0.04
1981	54	0.03	0.10	54	0.008	0.064	58	4.8	19.1	58	11.1	25.6	54	0.01	0.14
1982	57	0.02	0.10	58	0.010	0.058	53	4.3	13.3	58	10.9	34.8	58	0.02	0.09
1983	34	0.03	0.12	34	0.004	0.016	34	3.2	8.8	34	7.8	18.2	34	0.00	0.03
14016															
1976	8	0.01	0.04	18	0.013	0.031	96	4.0	20.0	105	8.7	33.4	18	0.00	0.02
1977	21	0.03	0.09	21	0.022	0.165	54	3.7	27.8	54	10.0	24.6	21	0.01	0.08
1978	26	0.02	0.06	26	0.016	0.194	53	4.6	24.6	53	11.2	35.3	26	0.00	0.10
1979	35	0.02	0.07	35	0.008	0.042	56	5.4	14.8	56	12.4	41.0	35	0.00	0.01
1980	25	0.02	0.10	25	0.010	0.064	56	4.8	11.4	56	11.5	25.1	25	0.01	0.10
1981	124	0.02	0.12	124	0.005	0.045	128	4.2	13.5	126	8.7	37.0	124	0.01	0.08
1982	339	0.01	0.10	339	0.006	0.100	339	3.5	23.3	339	9.3	48.7	338	0.01	0.14
1983	339	0.01	0.12	328	0.005	0.031	340	3.1	9.5	340	8.4	46.0	339	0.01	0.21
14030															
1978				11	0.009	0.013									
1979	45	0.01	0.05	50	0.006	0.032							45	0.00	0.02
1980	50	0.01	0.08	52	0.004	0.026							50	0.00	0.01
1981	51	0.02	0.10	56	0.004	0.034	51	4.4	13.7	51	9.5	27.6	51	0.01	0.03
1982	57	0.01	0.07	58	0.003	0.009	55	3.8	9.0	55	9.0	39.7	58	0.01	0.02
1983	56	0.01	0.03	56	0.002	0.009	34	3.2	9.0	34	7.1	14.5	57	0.00	0.02

Table A4. continued

Station and Year	Manganese # of samples	Manganese Avg.	Manganese Max.	Nickel # of samples	Nickel Avg.	Nickel Max	Nitrate # of samples	Nitrate Avg.	Nitrate Max	Sulphate # of samples	Sulphate Avg.	Sulphate Max	Vanadium # of samples	Vanadium Avg.	Vanadium Max
14031															
1978				12	0.016	0.057									
1979	46	0.02	0.07	54	0.009	0.171							46	0.00	0.01
1980	52	0.02	0.11	54	0.005	0.021							47	0.01	0.02
1981	52	0.02	0.14	58	0.004	0.020	50	3.7	10.1	52	9.6	28.2	52	0.01	0.02
1982	57	0.01	0.05	55	0.003	0.013	56	3.5	11.3	56	8.6	31.3	58	0.00	0.02
1983	55	0.01	0.04	55	0.002	0.016	33	3.6	11.3	33	7.8	16.1	55	0.00	0.03
14064															
1981	57	0.02	0.07	57	0.008	0.056	57	4.7	16.2	57	10.9	29.5	57	0.02	0.12
1982	52	0.03	0.21	53	0.009	0.067	51	4.3	15.6	51	10.3	32.6	52	0.01	0.11
1983	57	0.03	0.13	45	0.007	0.053	57	4.8	16.2	57	11.2	29.7	57	0.02	0.17
14054															
1976							54	3.7	13.2	61	8.9	34.8			
1977							49	3.8	20.2	49	10.1	25.7			
1978							49	4.8	20.4	49	11.5	37.0			
1979							55	5.1	14.3	55	12.5	39.2			
1980							57	5.2	14.8	57	12.4	27.6			
1981							57	4.3	14.1	57	10.2	30.0			
1982							58	3.8	11.1	58	10.3	41.5			
1983							24	3.6	10.2	24	7.6	14.1			
14051 (14151)															
1976							59	3.7	11.7	58	9.3	45.1			
1977							56	3.9	22.4	56	10.9	32.1			
1978							59	5.4	19.2	59	12.8	47.1			
1979							44	6.1	25.4	44	13.5	42.2			
1980							59	4.9	16.2	59	12.3	26.5			
1981							57	4.9	13.7	57	11.4	27.8			
1982							50	4.7	15.3	50	11.5	35.3			
1983							37	3.9	11.5	37	8.7	21.7			

APPENDIX 4

HYDROGEN SULPHIDE AND MERCAPTANS, CARBON MONOXIDE, OXIDES OF NITROGEN, HYDROCARBONS AND OZONE

Table A5. Summary of data for hydrogen sulphide and mercaptans, carbon monoxide, oxides of nitrogen and hydrocarbons.

Pollutant and Criteria	Station number	Year									
		1983	1982	1981	1980	1979	1978	1977	1976	1975	1974
Hydrogen sulphide and mercaptans											
Annual average (ppm)	14062	0.000	0.000	0.000	0.000	0.001	0.001				
	14049						0.001	0.001	0.001	0.001	0.007
Percentage of values above 1-hr criterion[(a)]	14062	0.01	0.00	0.01	0.00	0.01	0.00				
	14049						0.15	0.01	0.04	0.38	9.78
Carbon Monoxide											
Annual average (ppm)	14064	0	0	0	0	0	0				
	14049						1	2	1	1	1
Percentage of values above: 1-hr criterion	14064	0	0	0	0	0	0				
	14049						0	0	0	0	0
8-hr criterion	14064	0	0	0	0	0	0				
	14049						0	0	0	0	0

Note: (a) Criterion for hydrogen sulphide

Table A5. continued

Pollutant and Criteria	Station number	Year									
		1983	1982	1981	1980	1979	1978	1977	1976	1975	1974
Nitric oxide											
Annual average (ppm)	14064	0.01	0.01	0.01	0.01	0.02	0.02				
	14049						0.02	0.02	0.02		
Nitrogen dioxide											
Annual average (ppm)	14064	0.02	0.02	0.02	0.02	0.02	0.02				
	14049						0.03	0.03	0.03	0.02	
Percentage of values above:											
1-hr criterion	14064	0	0.01	0	0	0	0				
	14049					0	0	0	0		
24-hr criterion	14064	0	0	0	0	0	0				
	14049					0	0	0	0		

Table A5. continued

Pollutant and Criteria	Station number	Year									
		1983	1982	1981	1980	1979	1978	1977	1976	1975	1974
Total oxides of nitrogen											
Annual average (ppm)	14064	0.03	0.03	0.03	0.03	0.04	0.03				
	14049						0.05	0.05	0.05	0.05	
Total hydrocarbons											
Annual average (ppm)	14064	2.0	2.1	2.1	1.9	2.0	1.7				
	14049						2.6	2.4	2.3	2.6	2.8

Table A6. Summary of data for ozone

Station and Parameter	Year									
	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974
Station 14049										
Annual average (ppm)						0.023	0.020	0.019	0.024	0.018
Number of values above 1-hr criterion						51	87	56	132	80
Percentage of values above 1-hr criterion						1.1	1.0	0.7	1.9	1.1
Station 14064										
Annual average (ppm)	0.023	0.023	0.021	0.022	0.023	0.018				
Number of values above 1-hr criterion	116	56	67	68	130	56				
Percentage of values above 1-hr criterion	1.4	0.7	0.8	0.8	1.6	1.4				
Station 14118										
Annual average (ppm)	0.019	0.023	0.023	0.022	0.027	0.029	0.027			
Number of values above 1-hr criterion	16	10	85	39	138	249	182			
Percentage of values above 1-hr criterion	0.2	0.1	1.0	0.5	1.7	3.5	2.6			